Coastal Ocean Modeling & Dynamics

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LONG-TERM GOALS

The long-term goal of this research is to improve our ability to understand and predict environmental conditions in the coastal ocean.

OBJECTIVES

The central objective of the proposed research is to explore problems in coastal ocean modeling and dynamics, including Lagrangian trajectory analysis and the various roles played in coastal ocean predictability by basic physical elements of coastal ocean circulation. The research is being conducted by a graduate student, in collaboration with the PI.

APPROACH

The central activity of the proposed research is the development and analysis of a set of high-resolution numerical simulations of the Oregon coastal ocean that extend the recent work of Rivas and Samelson (2011), Kim et al. (2009), Kim et al. (2011), and Springer et al. (2009). The simulations and analysis are being carried out by graduate research assistant Rodrigo Duran, who passed the COAS physical oceanography Ph.D. qualifying exam in July 2009, and has recently finished his fourth year in the COAS physical oceanography graduate program. The research is currently focused primarily on describing and analyzing the dynamics of the poleward undercurrent (PUC). The PUC is a basic, persistent feature of eastern boundary current circulation regimes, but remains poorly understood and without an accepted dynamical explanation.

Research progress by Duran has included a nearly complete basic Eulerian and Lagrangian kinematic description of the undercurrent circulation in simulations for the year 2005, using an improved model configuration with smoothed bathymetry to prevent the development of spurious pressure gradients over the upper continental slope. To supplement the direct, Eulerian analysis of model mean poleward flow as a function of time and location, Duran has used forward integrations of conserved Lagrangian label and tracer fields, in order to obtain complementary and potentially more complete information on fluid parcel motion. Such techniques have been used successfully in some previous coastal simulations (e.g., Kuebel Cervantes et al., 2003, 2004; Springer et al., 2009) and offer the promise of a

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more complete representation and visualization of the complex patterns of Lagrangian motion in the coastal zone. On the other hand, the complexity of the Lagrangian motion – particularly on the long-term, seasonal timescales considered by Rivas and Samelson (2011) – presents challenges for the required inversion of the tracer fields. Current simulations indicate that the Lagrangian label and tracer methods yield useful results for this model integration on time scales extending to one month. This is sufficient to allow description and analysis of the Lagrangian PUC circulation.

WORK COMPLETED

The Eulerian and Lagrangian analysis of poleward mean flows in simulations for year 2005 has been nearly completed (R. Duran and R. Samelson, "Eulerian and Lagrangian kinematics of a model eastern-boundary poleward undercurrent," manuscript in preparation). The Eulerian analysis has focused on mean and fluctuating meridional (poleward) velocities and transports through zonal sections that have been divided in subregions by depth and offshore distance. The Lagrangian analysis has used both continuous Lagrangian label fields and discrete parcel or trajectory integrations. The analysis is based on simulation with an improved – relative to Rivas and Samelson (2011) – model configuration that includes daily boundary conditions from the Naval Research Laboratory NCOM-CCS regional model, finer vertical resolution, and bathymetry that has been smoothed to reduce pressure-gradient errors from the terrain-following coordinates at the PUC depths.

RESULTS

The results of the preliminary simulations show persistent Eulerian (Figs. 1, 2) and Lagrangian (Figs. 3,4) PUC flows in the model. The monthly mean flow in the PUC subregions, averaged over depths between 150 m and 500 m, is poleward over most of the meridional extent of the domain during most of the simulation year, except in April (Fig. 1). Averaged further zonally over the PUC subregions and meridionally over the domain, these monthly mean flows are typically 5-10 cm s^{-1} (Fig. 2). Continuous Lagrangian label fields reveal monthly mean poleward displacements of 100 km in these subregions during the months of stronger PUC flow (Fig. 3). Analysis of individual Lagrangian trajectories over longer periods shows that parcels can traverse the entire meridional extent of the domain, from south to north, in the PUC (Fig. 4).

IMPACT/APPLICATIONS

The results have impact and application for understanding of biological and any other related Lagrangian processes in the coastal zone, including dispersal of passive floating or submerged objects, and development of extreme biological conditions such as hypoxia or anoxia.

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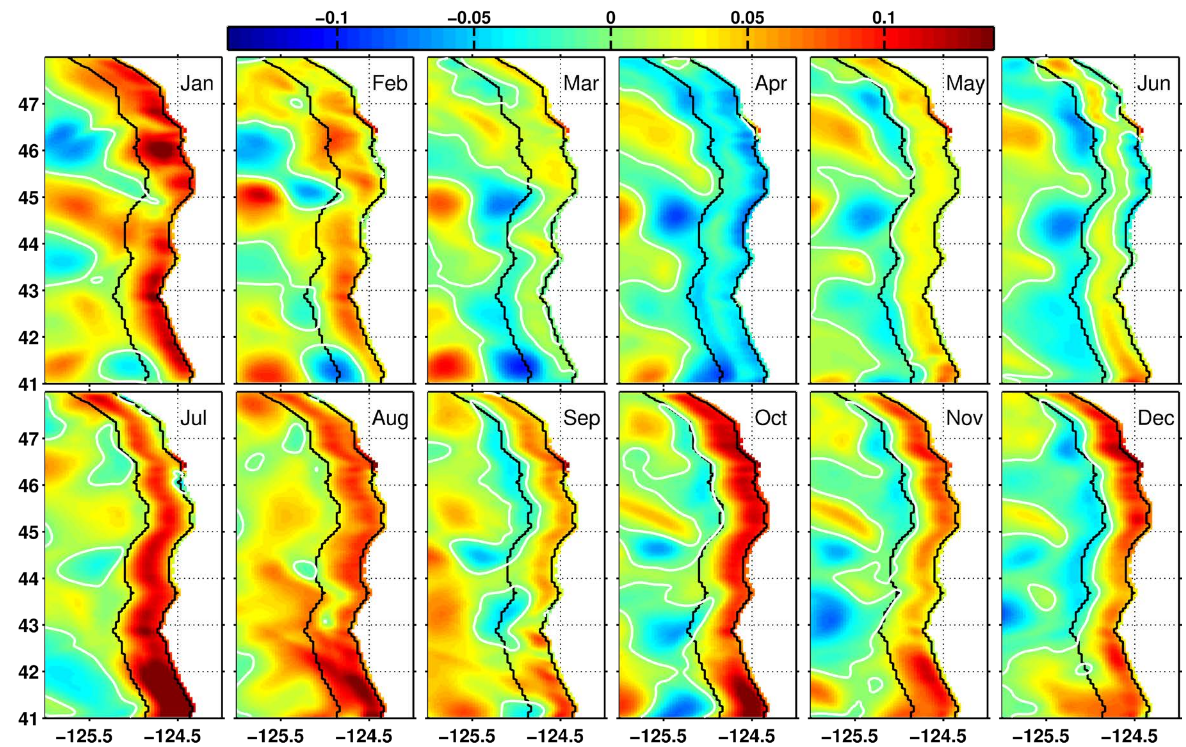

Figure 1. Monthly Eulerian-mean meridional velocity (m s^{-1} ; color range -0.14 to 0.14), averaged over the depth range 150 m to 500 m (or the bottom, in depths less than 500 m). The black contours indicate the 200-m isobath and the longitude points 36 km west of the 200-m isobath (approximately the 850-m isobath). In white is the zero-velocity contour.

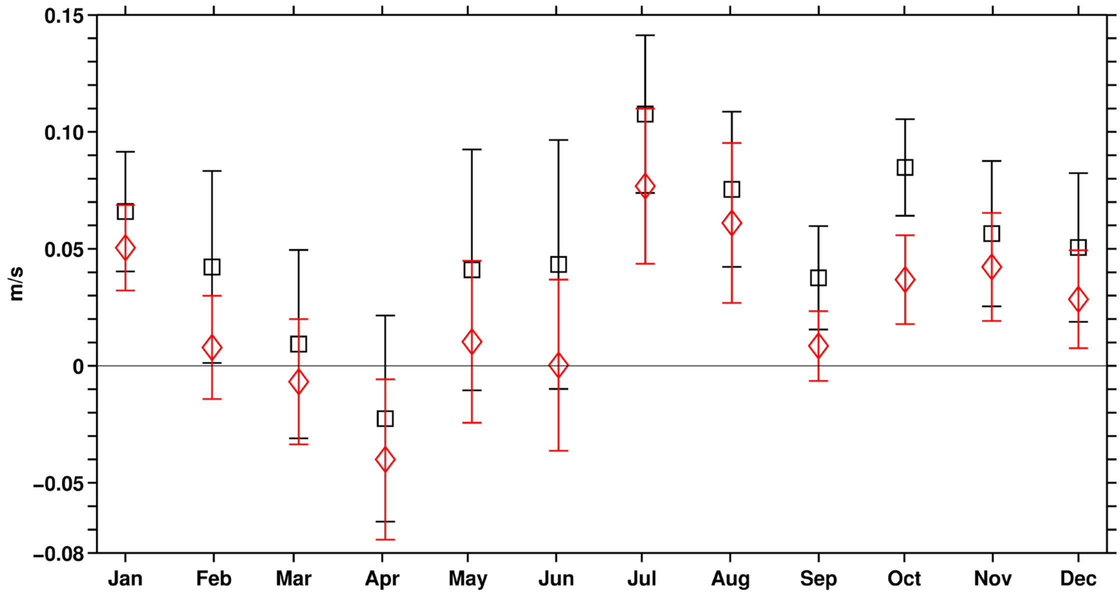

Figure 2. Monthly Eulerian-mean velocities averaged over the eastern (black) and western (red) halves of the region enclosed by black contours in Fig. 1. The error bars show the standard deviations of the monthly time series.

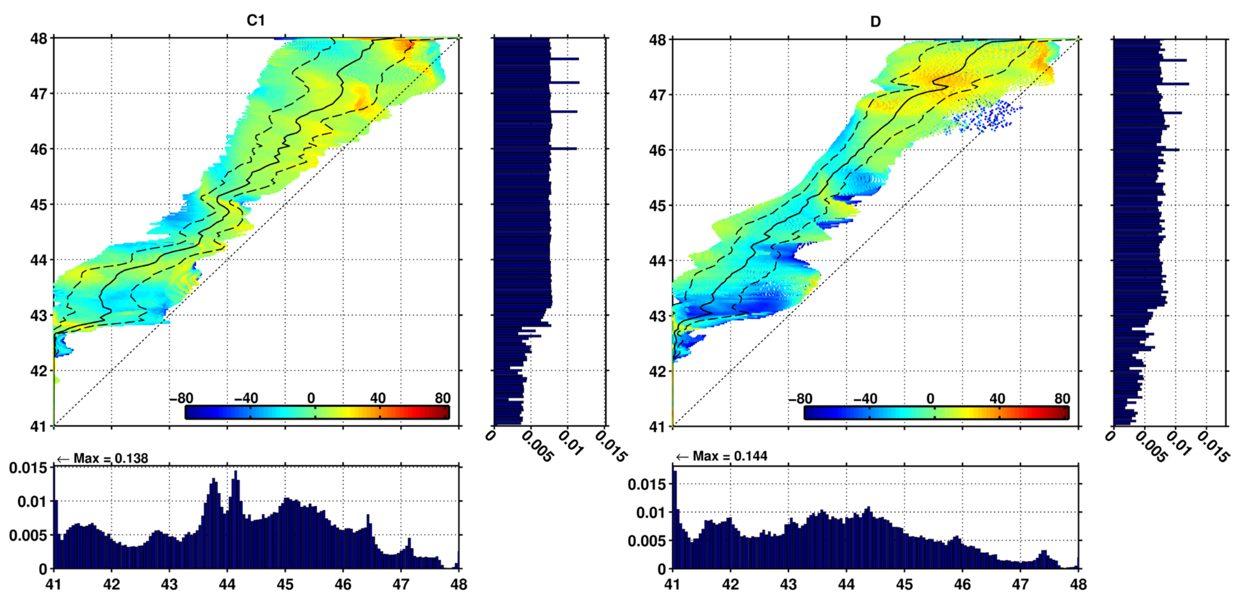

Figure 3. Scatter plot of initial (abscissa) vs. final (ordinate) latitude (°N) from Lagrangian label advection during August 2005, for parcels with final positions in the western (left panel) and eastern (right) halves of the region enclosed by black contours in Fig. 1. The histograms along the right and bottom axes show the distributions of initial and positions, respectively. The mean (solid black) ± one standard deviation (dashed black lines) of initial latitude at each final latitude are shown. There is a mean poleward displacement of approximately 100km at all latitudes. Color scale gives along-path upwelling (positive) or downwelling (negative) in meters.

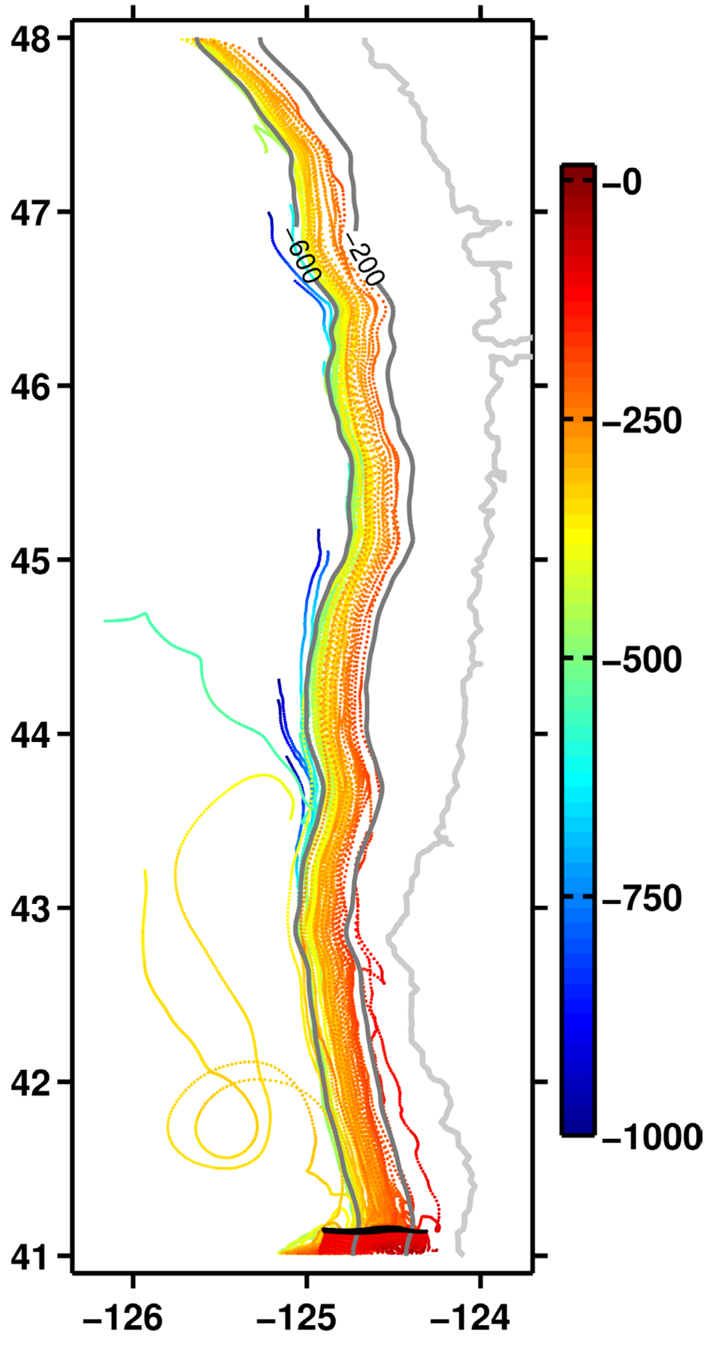

Figure 4. Lagrangian trajectories initialized on June 1st at 41.15 °N (black dots) and integrated for 120 days. Color represents along-path depth; initial depths ranged from 125 to 500m. The 200 and 600-m isobaths as well as the coastline are shown. Most of the shallower trajectories (depths < 150m) exit the domain to the south, while some of the deeper trajectories traverse the entire domain to the northern boundary.